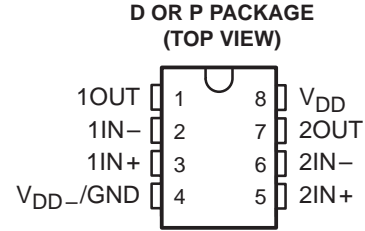


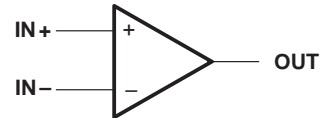
TLC252, TLC252A, TLC252B, TLC252Y, TLC25L2, TLC25L2A, TLC25L2B
 TLC25L2Y, TLC25M2, TLC25M2A, TLC25M2B, TLC25M2Y
LinCMOS™ DUAL OPERATIONAL AMPLIFIERS

SLOS002G – JUNE 1983 – REVISED AUGUST 1996

- A-Suffix Versions Offer 5-mV V_{IO}
- B-Suffix Versions Offer 2-mV V_{IO}
- Wide Range of Supply Voltages
1.4 V to 16 V
- True Single-Supply Operation
- Common-Mode Input Voltage Includes the Negative Rail
- Low Noise . . . 30 nV/ $\sqrt{\text{Hz}}$ Typ at $f = 1 \text{ kHz}$
(High-Bias Versions)



symbol (each amplifier)



description

The TLC252, TLC25L2, and TLC25M2 are low-cost, low-power dual operational amplifiers designed to operate with single or dual supplies. These devices utilize the Texas Instruments silicon gate LinCMOS™ process, giving them stable input offset voltages that are available in selected grades of 2, 5, or 10 mV maximum, very high input impedances, and extremely low input offset and bias currents. Because the input common-mode range extends to the negative rail and the power consumption is extremely low, this series is ideally suited for battery-powered or energy-conserving applications. The series offers operation down to a 1.4-V supply, is stable at unity gain, and has excellent noise characteristics.

These devices have internal electrostatic-discharge (ESD) protection circuits that prevent catastrophic failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.1. However, care should be exercised in handling these devices as exposure to ESD may result in a degradation of the device parametric performance.

AVAILABLE OPTIONS

T_A	V_{IOmax} AT 25°C	PACKAGED DEVICES		CHIP FORM (Y)
		SMALL OUTLINE (D)	PLASTIC DIP (P)	
0°C to 70°C	10 mV	TLC252CD	TLC252CP	TLC252Y
	5 mV	TLC252ACD	TLC252ACP	—
	2 mV	TLC252BCD	TLC252BCP	—
	10 mV	TLC25L2CD	TLC25L2CP	TLC25L2Y
	5 mV	TLC25L2ACD	TLC25L2ACP	—
	2 mV	TLC25L2BCD	TLC25L2BCP	—
	10 mV	TLC25M2CD	TLC25M2CP	TLC25M2Y
	5 mV	TLC25M2ACD	TLC25M2ACP	—
	2 mV	TLC25M2BCD	TLC25M2BCP	—

The D package is available taped and reeled. Add the suffix R to the device type (e.g., TLC252CDR). Chips are tested at 25°C.



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

LinCMOS is a trademark of Texas Instruments Incorporated.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.



POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

Copyright © 1996, Texas Instruments Incorporated

TLC252, TLC252A, TLC252B, TLC252Y, TLC25L2, TLC25L2A, TLC25L2B TLC25L2Y, TLC25M2, TLC25M2A, TLC25M2B, TLC25M2Y LinCMOS™ DUAL OPERATIONAL AMPLIFIERS

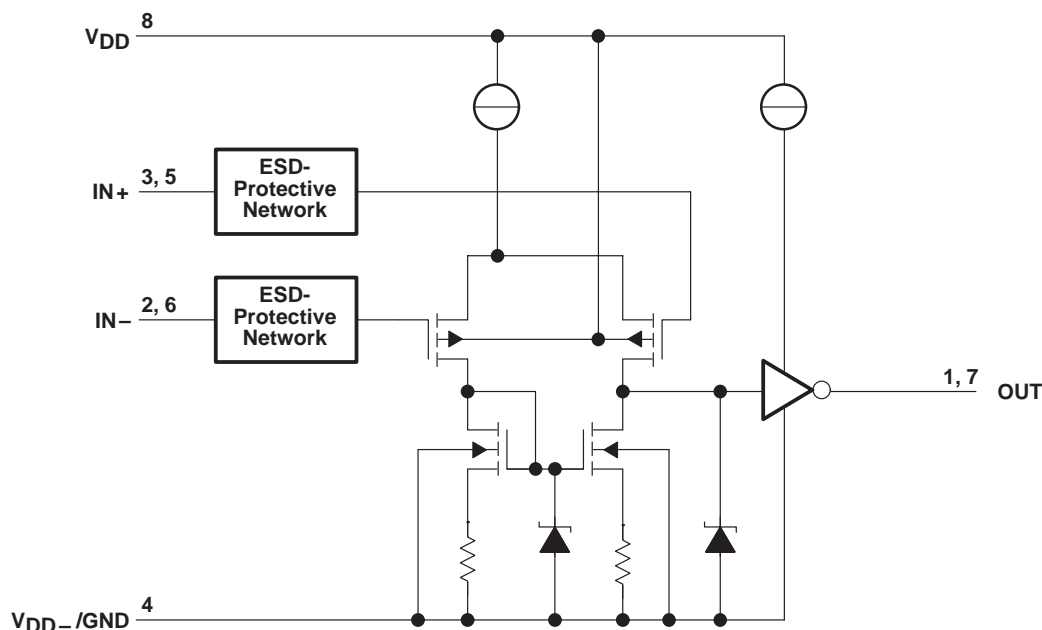
SLOS002G – JUNE 1983 – REVISED AUGUST 1996

description (continued)

Because of the extremely high input impedance and low input bias and offset currents, applications for the TLC252/25_2 series include many areas that have previously been limited to BIFET and NFET product types. Any circuit using high-impedance elements and requiring small offset errors is a good candidate for cost-effective use of these devices. Many features associated with bipolar technology are available with LinCMOS™ operational amplifiers without the power penalties of traditional bipolar devices. General applications such as transducer interfacing, analog calculations, amplifier blocks, active filters, and signal buffering are all easily designed with the TLC252/25_2 series devices. Remote and inaccessible equipment applications are possible using their low-voltage and low-power capabilities. The TLC252/25_2 series is well suited to solve the difficult problems associated with single-battery and solar-cell-powered applications. This series includes devices that are characterized for the commercial temperature range and are available in 8-pin plastic dip and the small-outline package. The device is also available in chip form.

The TLC252/25_2 series is characterized for operation from 0°C to 70°C.

equivalent schematic (each amplifier)

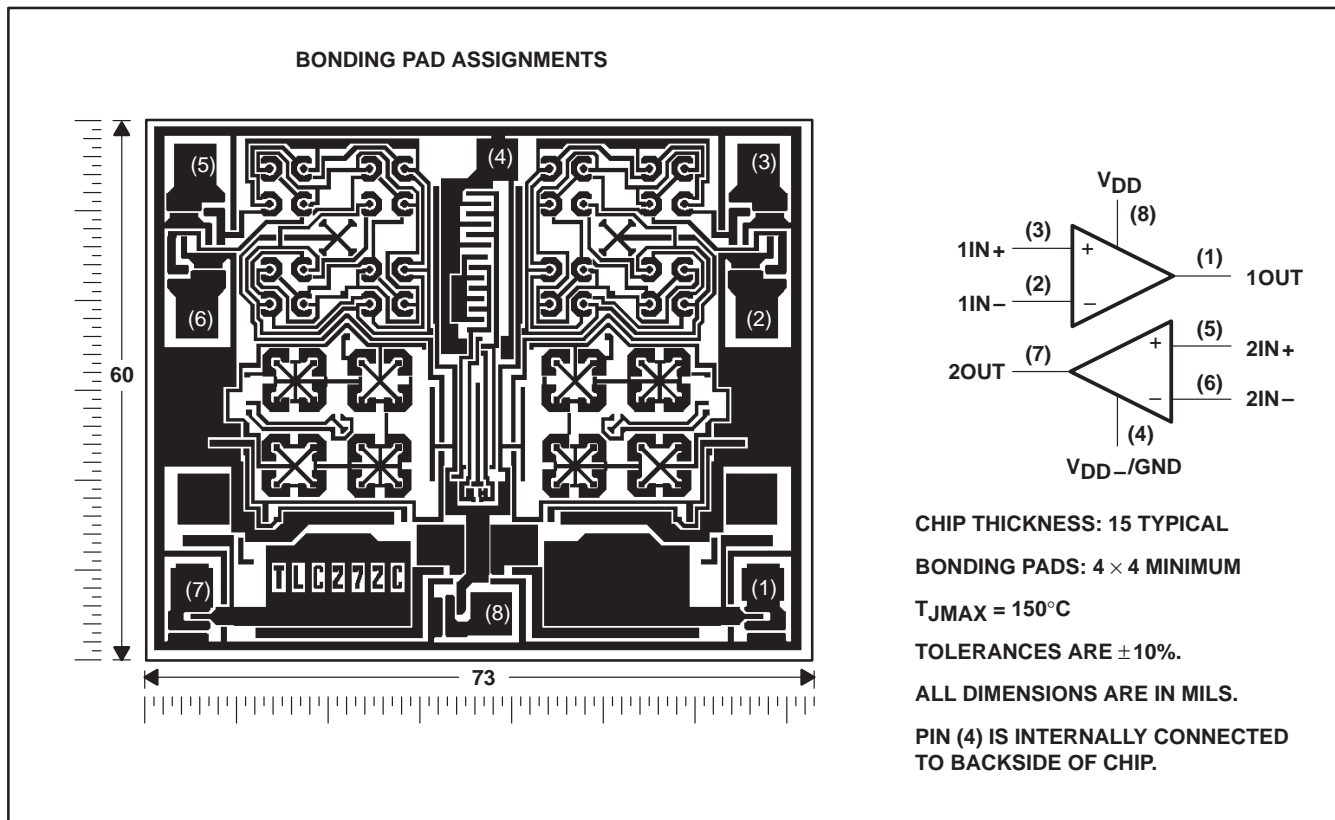


TLC252, TLC252A, TLC252B, TLC252Y, TLC25L2, TLC25L2A, TLC25L2B
 TLC25L2Y, TLC25M2, TLC25M2A, TLC25M2B, TLC25M2Y
 LinCMOS™ DUAL OPERATIONAL AMPLIFIERS

SLOS002G – JUNE 1983 – REVISED AUGUST 1996

TLC252Y, TLC25L2Y, and TLC25M2Y chip information

These chips, properly assembled, display characteristics similar to the TLC252/25_2. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



**TLC252, TLC252A, TLC252B, TLC252Y, TLC25L2, TLC25L2A, TLC25L2B
TLC25L2Y, TLC25M2, TLC25M2A, TLC25M2B, TLC25M2Y
LinCMOS™ DUAL OPERATIONAL AMPLIFIERS**

SLOS002G – JUNE 1983 – REVISED AUGUST 1996

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V_{DD} (see Note 1)	18 V
Differential input voltage, V_{ID} (see Note 2)	± 18 V
Input voltage range, V_I (any input)	-0.3 V to 18 V
Duration of short circuit at (or below) 25°C free-air temperature (see Note 3)	unlimited
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range, T_A	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

- NOTES: 1. All voltage values, except differential voltages, are with respect to V_{DD-}/GND .
 2. Differential voltages are at $IN+$, with respect to $IN-$.
 3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	$T_A \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 70^\circ\text{C}$ POWER RATING
D	725 mW	5.8 mW/°C	464 mW
P	1000 mW	8.0 mW/°C	640 mW

recommended operating conditions

		MIN	MAX	UNIT
Supply voltage, V_{DD}		1.4	16	V
Common-mode input voltage, V_{IC}	$V_{DD} = 1.4$ V	0	0.2	V
	$V_{DD} = 5$ V	-0.2	4	
	$V_{DD} = 10$ V	-0.2	9	
	$V_{DD} = 16$ V	-0.2	14	
Operating free-air temperature, T_A		0	70	°C



**TLC252, TLC252A, TLC252B, TLC252Y, TLC25L2, TLC25L2A, TLC25L2B
TLC25L2Y, TLC25M2, TLC25M2A, TLC25M2B, TLC25M2Y
LinCMOS™ DUAL OPERATIONAL AMPLIFIERS**

SLOS002G – JUNE 1983 – REVISED AUGUST 1996

electrical characteristics at specified free-air temperature, $V_{DD} = 1.4\text{ V}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS†	TLC252_C			TLC25L2_C			TLC25M2_C			UNIT	
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX		
V_{IO}	Input offset voltage	$V_O = 0.2\text{ V}$, $R_S = 50\ \Omega$	25°C	10			10			10			mV
			0°C to 70°C	12			12			12			
			25°C	5			5			5			
			0°C to 70°C	6.5			6.5			6.5			
			25°C	2			2			2			
			0°C to 70°C	3			3			3			
α_{VIO}	Average temperature coefficient of input offset voltage		25°C to 70°C	1			1			1			$\mu\text{V}/^\circ\text{C}$
I_{IO}	Input offset current	$V_O = 0.2\text{ V}$	25°C	1			1			1			pA
			0°C to 70°C	300			300			300			
I_{IB}	Input bias current	$V_O = 0.2\text{ V}$	25°C	1			1			1			pA
			0°C to 70°C	600			600			600			
V_{ICR}	Common-mode input voltage range		25°C	0 to 0.2			0 to 0.2			0 to 0.2			V
V_{OM}	Peak output voltage swing‡	$V_{ID} = 100\text{ mV}$	25°C	450	700	450	700	450	700	450	700	mV	
A_{VD}	Large-signal differential voltage amplification	$V_O = 100\text{ to }300\text{ mV}$, $R_S = 50\ \Omega$	25°C	10			20			20			V/mV
CMRR	Common-mode rejection ratio	$V_O = 0.2\text{ V}$, $V_{IC} = V_{ICRmin}$	25°C	60	77	60	77	60	77	60	77	dB	
I_{DD}	Supply current	$V_O = 0.2\text{ V}$, No load	25°C	300	375	25	34	200	250			μA	

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Unless otherwise noted, an output load resistor is connected from the output to ground and has the following value: for low bias $R_L = 1\text{ M}\Omega$, for medium bias $R_L = 100\text{ k}\Omega$, and for high bias $R_L = 10\text{ k}\Omega$.

‡ The output swings to the potential of V_{DD-}/GND .

operating characteristics, $V_{DD} = 1.4\text{ V}$, $T_A = 25^\circ\text{C}$

PARAMETER		TEST CONDITIONS	TLC252_C			TLC25L2_C			TLC25M2_C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
B_1	Unity-gain bandwidth	$A_V = 40\text{ dB}$, $C_L = 10\text{ pF}$, $R_S = 50\ \Omega$	12			12			12			kHz
SR	Slew rate at unity gain	See Figure 1	0.1			0.001			0.01			V/ μs
	Overshoot factor	See Figure 1	30%			35%			35%			



TLC252, TLC252A, TLC252B, TLC252Y, TLC25L2, TLC25L2A, TLC25L2B
 TLC25L2Y, TLC25M2, TLC25M2A, TLC25M2B, TLC25M2Y
 LinCMOS™ DUAL OPERATIONAL AMPLIFIERS

SLOS002G – JUNE 1983 – REVISED AUGUST 1996

electrical characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A^\dagger	TLC252C, TLC252AC, TLC252BC			UNIT
				MIN	TYP	MAX	
V_{IO}	Input offset voltage	$V_O = 1.4\text{ V}$, $R_S = 50\ \Omega$	$V_{IC} = 0$, $R_L = 10\text{ k}\Omega$	25°C	1.1	10	mV
				Full range		12	
		$V_O = 1.4\text{ V}$, $R_S = 50\ \Omega$	$V_{IC} = 0$, $R_L = 10\text{ k}\Omega$	25°C	0.9	5	
				Full range		6.5	
		$V_O = 1.4\text{ V}$, $R_S = 50\ \Omega$	$V_{IC} = 0$, $R_L = 10\text{ k}\Omega$	25°C	0.23	2	
				Full range		3	
α_{VIO}	Average temperature coefficient of input offset voltage		25°C to 70°C	1.8		$\mu\text{V}/^\circ\text{C}$	
I_{IO}	Input offset current (see Note 4)	$V_O = 2.5\text{ V}$	$V_{IC} = 2.5\text{ V}$	25°C	0.1		pA
				70°C	7	300	
I_{IB}	Input bias current (see Note 4)	$V_O = 2.5\text{ V}$	$V_{IC} = 2.5\text{ V}$	25°C	0.6		pA
				70°C	40	600	
V_{ICR}	Common-mode input voltage range (see Note 5)			25°C	-0.2 to 4	-0.3 to 4.2	V
				Full range	-0.2 to 3.5		V
V_{OH}	High-level output voltage	$V_{ID} = 100\text{ mV}$	$R_L = 10\text{ k}\Omega$	25°C	3.2	3.8	V
				0°C	3	3.8	
				70°C	3	3.8	
V_{OL}	Low-level output voltage	$V_{ID} = -100\text{ mV}$	$I_{OL} = 0$	25°C	0	50	mV
				0°C	0	50	
				70°C	0	50	
A_{VD}	Large-signal differential voltage amplification	$V_O = 0.25\text{ V to }2\text{ V}$	$R_L = 10\text{ k}\Omega$	25°C	5	23	V/mV
				0°C	4	27	
				70°C	4	20	
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICRmin}$		25°C	65	80	dB
				0°C	60	84	
				70°C	60	85	
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{DD}$)	$V_{DD} = 5\text{ V to }10\text{ V}$	$V_O = 1.4\text{ V}$	25°C	65	95	dB
				0°C	60	94	
				70°C	60	96	
I_{DD}	Supply current (two amplifiers)	$V_O = 2.5\text{ V}$, No load	$V_{IC} = 2.5\text{ V}$	25°C	1.4	3.2	mA
				0°C	1.6	3.6	
				70°C	1.2	2.6	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.



**TLC252, TLC252A, TLC252B, TLC252Y, TLC25L2, TLC25L2A, TLC25L2B
TLC25L2Y, TLC25M2, TLC25M2A, TLC25M2B, TLC25M2Y
LinCMOS™ DUAL OPERATIONAL AMPLIFIERS**

SLOS002G – JUNE 1983 – REVISED AUGUST 1996

electrical characteristics at specified free-air temperature, $V_{DD} = 10\text{ V}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A †	TLC252C, TLC252AC, TLC252BC			UNIT	
				MIN	TYP	MAX		
V_{IO}	Input offset voltage	$V_O = 1.4\text{ V}$, $R_S = 50\ \Omega$	$V_{IC} = 0$, $R_L = 10\text{ k}\Omega$	25°C	1.1	10	mV	
				Full range		12		
		TLC252AC	$V_O = 1.4\text{ V}$, $R_S = 50\ \Omega$	$V_{IC} = 0$, $R_L = 10\text{ k}\Omega$	25°C	0.9		5
					Full range			6.5
		TLC252BC	$V_O = 1.4\text{ V}$, $R_S = 50\ \Omega$	$V_{IC} = 0$, $R_L = 10\text{ k}\Omega$	25°C	0.29		2
					Full range			3
α_{VIO}	Average temperature coefficient of input offset voltage		25°C to 70°C	2		$\mu\text{V}/^\circ\text{C}$		
I_{IO}	Input offset current (see Note 4)	$V_O = 2.5\text{ V}$	$V_{IC} = 2.5\text{ V}$	25°C	0.1		pA	
				70°C	7	300		
I_{IB}	Input bias current (see Note 4)	$V_O = 2.5\text{ V}$	$V_{IC} = 2.5\text{ V}$	25°C	0.6		pA	
				70°C	50	600		
V_{ICR}	Common-mode input voltage range (see Note 5)			25°C	-0.2 to 9	-0.3 to 9.2	V	
				Full range	-0.2 to 8.5		V	
V_{OH}	High-level output voltage	$V_{ID} = 100\text{ mV}$	$R_L = 10\text{ k}\Omega$	25°C	8	8.5	V	
				0°C	8	8.5		
				70°C	7.8	8.4		
V_{OL}	Low-level output voltage	$V_{ID} = -100\text{ mV}$	$I_{OL} = 0$	25°C	0	50	mV	
				0°C	0	50		
				70°C	0	50		
A_{VD}	Large-signal differential voltage amplification	$V_O = 1\text{ V to }6\text{ V}$	$R_L = 10\text{ k}\Omega$	25°C	10	36	V/mV	
				0°C	7.5	42		
				70°C	7.5	32		
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICRmin}$		25°C	65	85	dB	
				0°C	60	88		
				70°C	60	88		
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{DD}$)	$V_{DD} = 5\text{ V to }10\text{ V}$	$V_O = 1.4\text{ V}$	25°C	65	95	dB	
				0°C	60	94		
				70°C	60	96		
I_{DD}	Supply current (two amplifiers)	$V_O = 5\text{ V}$, No load	$V_{IC} = 5\text{ V}$	25°C	1.9	4	mA	
				0°C	2.3	4.4		
				70°C	1.6	3.4		

† Full range is 0°C to 70°C.

- NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.
5. This range also applies to each input individually.

TLC252, TLC252A, TLC252B, TLC252Y, TLC25L2, TLC25L2A, TLC25L2B
 TLC25L2Y, TLC25M2, TLC25M2A, TLC25M2B, TLC25M2Y
 LinCMOS™ DUAL OPERATIONAL AMPLIFIERS

SLOS002G – JUNE 1983 – REVISED AUGUST 1996

operating characteristics, $V_{DD} = 5\text{ V}$

PARAMETER	TEST CONDITIONS	T_A	TLC252C, TLC252AC, TLC252BC			UNIT
			MIN	TYP	MAX	
SR Slew rate at unity gain	$R_L = 10\text{ k}\Omega$, See Figure 1 $C_L = 20\text{ pF}$	$V_{I(PP)} = 1\text{ V}$	25°C	3.6		V/ μ s
			0°C	4		
			70°C	3		
		$V_{I(PP)} = 2.5\text{ V}$	25°C	2.9		
			0°C	3.1		
			70°C	2.5		
V_n Equivalent input noise voltage	$f = 1\text{ kHz}$, $R_S = 20\ \Omega$, See Figure 2	25°C	25		nV/ $\sqrt{\text{Hz}}$	
B_{OM} Maximum output-swing bandwidth	$V_O = V_{OH}$, See Figure 1 $C_L = 20\text{ pF}$, $R_L = 100\text{ k}\Omega$	25°C	320		kHz	
		0°C	340			
		70°C	260			
B_1 Unity-gain bandwidth	$V_I = 10\text{ mV}$, $C_L = 20\text{ pF}$, See Figure 3	25°C	1.7		MHz	
		0°C	2			
		70°C	1.3			
ϕ_m Phase margin	$V_I = 10\text{ mV}$, See Figure 3 $f = B_1$, $C_L = 20\text{ pF}$	25°C	46°			
		0°C	47°			
		70°C	43°			

operating characteristics, $V_{DD} = 10\text{ V}$

PARAMETER	TEST CONDITIONS	T_A	TLC252C, TLC252AC, TLC252BC			UNIT
			MIN	TYP	MAX	
SR Slew rate at unity gain	$R_L = 10\text{ k}\Omega$, See Figure 1 $C_L = 20\text{ pF}$	$V_{I(PP)} = 1\text{ V}$	25°C	5.3		V/ μ s
			0°C	5.9		
			70°C	4.3		
		$V_{I(PP)} = 5.5\text{ V}$	25°C	4.6		
			0°C	5.1		
			70°C	3.8		
V_n Equivalent input noise voltage	$f = 1\text{ kHz}$, $R_S = 20\ \Omega$, See Figure 2	25°C	25		nV/ $\sqrt{\text{Hz}}$	
B_{OM} Maximum output-swing bandwidth	$V_O = V_{OH}$, See Figure 1 $C_L = 20\text{ pF}$, $R_L = 100\text{ k}\Omega$	25°C	200		kHz	
		0°C	220			
		70°C	140			
B_1 Unity-gain bandwidth	$V_I = 10\text{ mV}$, $C_L = 20\text{ pF}$, See Figure 3	25°C	2.2		MHz	
		0°C	2.5			
		70°C	1.8			
ϕ_m Phase margin	$V_I = 10\text{ mV}$, See Figure 3 $f = B_1$, $C_L = 20\text{ pF}$	25°C	49°			
		0°C	50°			
		70°C	46°			



**TLC252, TLC252A, TLC252B, TLC252Y, TLC25L2, TLC25L2A, TLC25L2B
TLC25L2Y, TLC25M2, TLC25M2A, TLC25M2B, TLC25M2Y
LinCMOS™ DUAL OPERATIONAL AMPLIFIERS**

SLOS002G – JUNE 1983 – REVISED AUGUST 1996

electrical characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A †	TLC25L2C TLC25L2AC TLC25L2BC			UNIT
				MIN	TYP	MAX	
V_{IO}	Input offset voltage	TLC252C $V_O = 1.4\text{ V}$, $R_S = 50\ \Omega$,	$V_{IC} = 0$, $R_L = 1\text{ M}\Omega$	25°C	1.1	10	mV
				Full range		12	
		TLC252AC $V_O = 1.4\text{ V}$, $R_S = 50\ \Omega$,	$V_{IC} = 0$, $R_L = 1\text{ M}\Omega$	25°C	0.9	5	
				Full range		6.5	
		TLC252BC $V_O = 1.4\text{ V}$, $R_S = 50\ \Omega$,	$V_{IC} = 0$, $R_L = 1\text{ M}\Omega$	25°C	0.204	2	
				Full range		3	
α_{VIO}	Average temperature coefficient of input offset voltage		25°C to 70°C	1.1		$\mu\text{V}/^\circ\text{C}$	
I_{IO}	Input offset current (see Note 4)	$V_O = 2.5\text{ V}$,	$V_{IC} = 2.5\text{ V}$	25°C	0.1		pA
				70°C	7	300	
I_{IB}	Input bias current (see Note 4)	$V_O = 2.5\text{ V}$,	$V_{IC} = 2.5\text{ V}$	25°C	0.6		pA
				70°C	50	600	
V_{ICR}	Common-mode input voltage range (see Note 5)			25°C	-0.2 to 4	-0.3 to 4.2	V
				Full range	-0.2 to 3.5		V
V_{OH}	High-level output voltage	$V_{ID} = 100\text{ mV}$,	$R_L = 1\text{ M}\Omega$	25°C	3.2	4.1	V
				0°C	3	4.1	
				70°C	3	4.2	
V_{OL}	Low-level output voltage	$V_{ID} = -100\text{ mV}$,	$I_{OL} = 0$	25°C	0	50	mV
				0°C	0	50	
				70°C	0	50	
A_{VD}	Large-signal differential voltage amplification	$V_O = 0.25\text{ V to }2\text{ V}$,	$R_L = 1\text{ M}\Omega$	25°C	50	700	V/mV
				0°C	50	700	
				70°C	50	380	
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICRmin}$		25°C	65	94	dB
				0°C	60	95	
				70°C	60	95	
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{DD}$)	$V_{DD} = 5\text{ V to }10\text{ V}$,	$V_O = 1.4\text{ V}$	25°C	70	97	dB
				0°C	60	97	
				70°C	60	98	
I_{DD}	Supply current (two amplifiers)	$V_O = 2.5\text{ V}$, No load	$V_{IC} = 2.5\text{ V}$,	25°C	20	34	μA
				0°C	24	42	
				70°C	16	28	

† Full range is 0°C to 70°C.

- NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.
5. This range also applies to each input individually.

TLC252, TLC252A, TLC252B, TLC252Y, TLC25L2, TLC25L2A, TLC25L2B
 TLC25L2Y, TLC25M2, TLC25M2A, TLC25M2B, TLC25M2Y
 LinCMOS™ DUAL OPERATIONAL AMPLIFIERS

SLOS002G – JUNE 1983 – REVISED AUGUST 1996

electrical characteristics at specified free-air temperature, $V_{DD} = 10\text{ V}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A †	TLC25L2C TLC25L2AC TLC25L2BC			UNIT
				MIN	TYP	MAX	
V_{IO}	Input offset voltage	TLC252C $V_O = 1.4\text{ V}$, $R_S = 50\ \Omega$, $V_{IC} = 0$, $R_L = 1\text{ M}\Omega$	25°C	1.1	10	mV	
			Full range		12		
		TLC252AC $V_O = 1.4\text{ V}$, $R_S = 50\ \Omega$, $V_{IC} = 0$, $R_L = 1\text{ M}\Omega$	25°C	0.9	5		
			Full range		6.5		
		TLC252BC $V_O = 1.4\text{ V}$, $R_S = 50\ \Omega$, $V_{IC} = 0$, $R_L = 1\text{ M}\Omega$	25°C	0.235	2		
			Full range		3		
α_{VIO}	Average temperature coefficient of input offset voltage		25°C to 70°C	1		$\mu\text{V}/^\circ\text{C}$	
I_{IO}	Input offset current (see Note 4)	$V_O = 5\text{ V}$, $V_{IC} = 5\text{ V}$	25°C	0.1		pA	
			70°C	8	300		
I_{IB}	Input bias current (see Note 4)	$V_O = 5\text{ V}$, $V_{IC} = 5\text{ V}$	25°C	0.7		pA	
			70°C	50	600		
V_{ICR}	Common-mode input voltage range (see Note 5)		25°C	-0.2 to 9	-0.3 to 9.2	V	
			Full range	-0.2 to 8.5			
V_{OH}	High-level output voltage	$V_{ID} = 100\text{ mV}$, $R_L = 1\text{ M}\Omega$	25°C	8	8.9	V	
			0°C	7.8	8.9		
			70°C	7.8	8.9		
V_{OL}	Low-level output voltage	$V_{ID} = -100\text{ mV}$, $I_{OL} = 0$	25°C	0	50	mV	
			0°C	0	50		
			70°C	0	50		
A_{VD}	Large-signal differential voltage amplification	$V_O = 1\text{ V to }6\text{ V}$, $R_L = 1\text{ M}\Omega$	25°C	50	860	V/mV	
			0°C	50	1025		
			70°C	50	660		
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICRmin}$	25°C	65	97	dB	
			0°C	60	97		
			70°C	60	97		
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{DD}$)	$V_{DD} = 5\text{ V to }10\text{ V}$, $V_O = 1.4\text{ V}$	25°C	70	97	dB	
			0°C	60	97		
			70°C	60	98		
I_{DD}	Supply current (two amplifiers)	$V_O = 5\text{ V}$, No load $V_{IC} = 5\text{ V}$	25°C	29	46	μA	
			0°C	36	66		
			70°C	22	40		

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.



TLC252, TLC252A, TLC252B, TLC252Y, TLC25L2, TLC25L2A, TLC25L2B
TLC25L2Y, TLC25M2, TLC25M2A, TLC25M2B, TLC25M2Y
LinCMOS™ DUAL OPERATIONAL AMPLIFIERS

SLOS002G – JUNE 1983 – REVISED AUGUST 1996

operating characteristics, $V_{DD} = 5\text{ V}$

PARAMETER	TEST CONDITIONS	T_A	TLC25L2C TLC25L2AC TLC25L2BC			UNIT
			MIN	TYP	MAX	
SR Slew rate at unity gain	$R_L = 1\text{ M}\Omega$, $C_L = 20\text{ pF}$, See Figure 1	$V_{I(PP)} = 1\text{ V}$	25°C	0.03		V/ μ s
			0°C	0.04		
			70°C	0.03		
		$V_{I(PP)} = 2.5\text{ V}$	25°C	0.03		
			0°C	0.03		
			70°C	0.02		
V_n Equivalent input noise voltage	$f = 1\text{ kHz}$, $R_S = 20\ \Omega$, See Figure 2	25°C	68		nV/ $\sqrt{\text{Hz}}$	
B_{OM} Maximum output-swing bandwidth	$V_O = V_{OH}$, $C_L = 20\text{ pF}$, See Figure 1	$R_L = 1\text{ M}\Omega$	25°C	5		kHz
			0°C	6		
			70°C	4.5		
B_1 Unity-gain bandwidth	$V_I = 10\text{ mV}$, $C_L = 20\text{ pF}$, See Figure 3	See Figure 3	25°C	85		MHz
			0°C	100		
			70°C	65		
ϕ_m Phase margin	$V_I = 10\text{ mV}$, $f = B_1$, See Figure 3	$C_L = 20\text{ pF}$	25°C	34°		
			0°C	36°		
			70°C	30°		

operating characteristics, $V_{DD} = 10\text{ V}$

PARAMETER	TEST CONDITIONS	T_A	TLC25L2C TLC25L2AC TLC25L2BC			UNIT
			MIN	TYP	MAX	
SR Slew rate at unity gain	$R_L = 1\text{ M}\Omega$, $C_L = 20\text{ pF}$, See Figure 1	$V_{I(PP)} = 1\text{ V}$	25°C	0.05		V/ μ s
			0°C	0.05		
			70°C	0.04		
		$V_{I(PP)} = 5.5\text{ V}$	25°C	0.04		
			0°C	0.05		
			70°C	0.04		
V_n Equivalent input noise voltage	$f = 1\text{ kHz}$, $R_S = 20\ \Omega$, See Figure 2	25°C	68		nV/ $\sqrt{\text{Hz}}$	
B_{OM} Maximum output-swing bandwidth	$V_O = V_{OH}$, $C_L = 20\text{ pF}$, See Figure 1	$R_L = 1\text{ M}\Omega$	25°C	1		kHz
			0°C	1.3		
			70°C	0.9		
B_1 Unity-gain bandwidth	$V_I = 10\text{ mV}$, $C_L = 20\text{ pF}$, See Figure 3	See Figure 3	25°C	110		MHz
			0°C	125		
			70°C	90		
ϕ_m Phase margin	$V_I = 10\text{ mV}$, $f = B_1$, See Figure 3	$C_L = 20\text{ pF}$	25°C	38°		
			0°C	40°		
			70°C	34°		



TLC252, TLC252A, TLC252B, TLC252Y, TLC25L2, TLC25L2A, TLC25L2B
 TLC25L2Y, TLC25M2, TLC25M2A, TLC25M2B, TLC25M2Y
 LinCMOS™ DUAL OPERATIONAL AMPLIFIERS

SLOS002G – JUNE 1983 – REVISED AUGUST 1996

electrical characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A †	TLC25M2C TLC25M2AC TLC25M2BC			UNIT
				MIN	TYP	MAX	
V_{IO}	Input offset voltage	TLC252C $V_O = 1.4\text{ V}$, $R_S = 50\ \Omega$, $V_{IC} = 0$, $R_L = 100\text{ k}\Omega$	25°C	1.1	10	mV	
			Full range		12		
		TLC252AC $V_O = 1.4\text{ V}$, $R_S = 50\ \Omega$, $V_{IC} = 0$, $R_L = 100\text{ k}\Omega$	25°C	0.9	5		
			Full range		6.5		
		TLC252BC $V_O = 1.4\text{ V}$, $R_S = 50\ \Omega$, $V_{IC} = 0$, $R_L = 100\text{ k}\Omega$	25°C	0.22	2		
			Full range		3		
α_{VIO}	Average temperature coefficient of input offset voltage		25°C to 70°C	1.7		$\mu\text{V}/^\circ\text{C}$	
I_{IO}	Input offset current (see Note 4)	$V_O = 2.5\text{ V}$, $V_{IC} = 2.5\text{ V}$	25°C	0.1		pA	
			70°C	7	300		
I_{IB}	Input bias current (see Note 4)	$V_O = 2.5\text{ V}$, $V_{IC} = 2.5\text{ V}$	25°C	0.6		pA	
			70°C	40	600		
V_{ICR}	Common-mode input voltage range (see Note 5)		25°C	-0.2 to 4	-0.3 to 4.2	V	
			Full range	-0.2 to 3.5			
V_{OH}	High-level output voltage	$V_{ID} = 100\text{ mV}$, $R_L = 100\text{ k}\Omega$	25°C	3.2	3.9	V	
			0°C	3	3.9		
			70°C	3	4		
V_{OL}	Low-level output voltage	$V_{ID} = -100\text{ mV}$, $I_{OL} = 0$	25°C	0	50	mV	
			0°C	0	50		
			70°C	0	50		
A_{VD}	Large-signal differential voltage amplification	$V_O = 0.25\text{ V to }2\text{ V}$, $R_L = 100\text{ k}\Omega$	25°C	25	170	V/mV	
			0°C	15	200		
			70°C	15	140		
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICRmin}$	25°C	65	91	dB	
			0°C	60	91		
			70°C	60	92		
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{DD}$)	$V_{DD} = 5\text{ V to }10\text{ V}$, $V_O = 1.4\text{ V}$	25°C	70	93	dB	
			0°C	60	92		
			70°C	60	94		
I_{DD}	Supply current (two amplifiers)	$V_O = 2.5\text{ V}$, No load $V_{IC} = 2.5\text{ V}$	25°C	210	560	μA	
			0°C	250	640		
			70°C	170	440		

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.



TLC252, TLC252A, TLC252B, TLC252Y, TLC25L2, TLC25L2A, TLC25L2B
TLC25L2Y, TLC25M2, TLC25M2A, TLC25M2B, TLC25M2Y
LinCMOS™ DUAL OPERATIONAL AMPLIFIERS

SLOS002G – JUNE 1983 – REVISED AUGUST 1996

electrical characteristics at specified free-air temperature, $V_{DD} = 10\text{ V}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A †	TLC25M2C TLC25M2AC TLC25M2BC			UNIT
				MIN	TYP	MAX	
V_{IO}	Input offset voltage	TLC252C $V_O = 1.4\text{ V}$, $R_S = 50\ \Omega$, $V_{IC} = 0$, $R_L = 100\text{ k}\Omega$	25°C	1.1	10	mV	
			Full range		12		
		TLC252AC $V_O = 1.4\text{ V}$, $R_S = 50\ \Omega$, $V_{IC} = 0$, $R_L = 100\text{ k}\Omega$	25°C	0.9	5		
			Full range		6.5		
		TLC252BC $V_O = 1.4\text{ V}$, $R_S = 50\ \Omega$, $V_{IC} = 0$, $R_L = 100\text{ k}\Omega$	25°C	0.224	2		
			Full range		3		
α_{VIO}	Average temperature coefficient of input offset voltage		25°C to 70°C	2.1		$\mu\text{V}/^\circ\text{C}$	
I_{IO}	Input offset current (see Note 4)	$V_O = 5\text{ V}$, $V_{IC} = 5\text{ V}$	25°C	0.1		pA	
			70°C	7	300		
I_{IB}	Input bias current (see Note 4)	$V_O = 5\text{ V}$, $V_{IC} = 5\text{ V}$	25°C	0.7		pA	
			70°C	50	600		
V_{ICR}	Common-mode input voltage range (see Note 5)		25°C	-0.2 to 9	-0.3 to 9.2	V	
			Full range	-0.2 to 8.5			
V_{OH}	High-level output voltage	$V_{ID} = 100\text{ mV}$, $R_L = 100\text{ k}\Omega$	25°C	8	8.7	V	
			0°C	7.8	8.7		
			70°C	7.8	8.7		
V_{OL}	Low-level output voltage	$V_{ID} = -100\text{ mV}$, $I_{OL} = 0$	25°C	0	50	mV	
			0°C	0	50		
			70°C	0	50		
A_{VD}	Large-signal differential voltage amplification	$V_O = 1\text{ V to }6\text{ V}$, $R_L = 100\text{ k}\Omega$	25°C	25	275	V/mV	
			0°C	15	320		
			70°C	15	230		
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICRmin}$	25°C	65	94	dB	
			0°C	60	94		
			70°C	60	94		
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{DD}$)	$V_{DD} = 5\text{ V to }10\text{ V}$, $V_O = 1.4\text{ V}$	25°C	70	93	dB	
			0°C	60	92		
			70°C	60	94		
I_{DD}	Supply current (two amplifiers)	$V_O = 5\text{ V}$, No load $V_{IC} = 5\text{ V}$	25°C	285	600	μA	
			0°C	345	800		
			70°C	220	560		

† Full range is 0°C to 70°C.

- NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.
5. This range also applies to each input individually.



TLC252, TLC252A, TLC252B, TLC252Y, TLC25L2, TLC25L2A, TLC25L2B
 TLC25L2Y, TLC25M2, TLC25M2A, TLC25M2B, TLC25M2Y
 LinCMOS™ DUAL OPERATIONAL AMPLIFIERS

SLOS002G – JUNE 1983 – REVISED AUGUST 1996

operating characteristics, $V_{DD} = 5\text{ V}$

PARAMETER	TEST CONDITIONS	T_A	TLC25M2C TLC25M2AC TLC25M2BC			UNIT
			MIN	TYP	MAX	
SR Slew rate at unity gain	$R_L = 100\text{ k}\Omega$, $C_L = 20\text{ pF}$, See Figure 1	$V_{I(PP)} = 1\text{ V}$	25°C	0.43		V/ μs
			0°C	0.46		
			70°C	0.36		
		$V_{I(PP)} = 2.5\text{ V}$	25°C	0.40		
			0°C	0.43		
			70°C	0.34		
V_n Equivalent input noise voltage	$f = 1\text{ kHz}$, $R_S = 20\ \Omega$, See Figure 2	25°C	32		nV/ $\sqrt{\text{Hz}}$	
B_{OM} Maximum output-swing bandwidth	$V_O = V_{OH}$, $C_L = 20\text{ pF}$, See Figure 1	$R_L = 100\text{ k}\Omega$	25°C	55		kHz
			0°C	60		
			70°C	50		
B_1 Unity-gain bandwidth	$V_I = 10\text{ mV}$, $C_L = 20\text{ pF}$, See Figure 3	25°C	525		MHz	
		0°C	600			
		70°C	400			
ϕ_m Phase margin	$V_I = 10\text{ mV}$, $f = B_1$, See Figure 3	$C_L = 20\text{ pF}$	25°C	40°		
			0°C	41°		
			70°C	39°		

operating characteristics, $V_{DD} = 10\text{ V}$

PARAMETER	TEST CONDITIONS	T_A	TLC25M2C TLC25M2AC TLC25M2BC			UNIT
			MIN	TYP	MAX	
SR Slew rate at unity gain	$R_L = 100\text{ k}\Omega$, $C_L = 20\text{ pF}$, See Figure 1	$V_{I(PP)} = 1\text{ V}$	25°C	0.62		V/ μs
			0°C	0.67		
			70°C	0.51		
		$V_{I(PP)} = 5.5\text{ V}$	25°C	0.56		
			0°C	0.61		
			70°C	0.46		
V_n Equivalent input noise voltage	$f = 1\text{ kHz}$, $R_S = 20\ \Omega$, See Figure 2	25°C	32		nV/ $\sqrt{\text{Hz}}$	
B_{OM} Maximum output-swing bandwidth	$V_O = V_{OH}$, $C_L = 20\text{ pF}$, See Figure 1	$R_L = 100\text{ k}\Omega$	25°C	35		kHz
			0°C	40		
			70°C	30		
B_1 Unity-gain bandwidth	$V_I = 10\text{ mV}$, $C_L = 20\text{ pF}$, See Figure 3	25°C	635		MHz	
		0°C	710			
		70°C	510			
ϕ_m Phase margin	$V_I = 10\text{ mV}$, $f = B_1$, See Figure 3	$C_L = 20\text{ pF}$	25°C	43°		
			0°C	44°		
			70°C	42°		



**TLC252, TLC252A, TLC252B, TLC252Y, TLC25L2, TLC25L2A, TLC25L2B
TLC25L2Y, TLC25M2, TLC25M2A, TLC25M2B, TLC25M2Y
LinCMOS™ DUAL OPERATIONAL AMPLIFIERS**

SLOS002G – JUNE 1983 – REVISED AUGUST 1996

electrical characteristics, $V_{DD} = 5\text{ V}$, $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	TLC252Y			TLC25L2Y			TLC25M2Y			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage $V_O = 1.4\text{ V}$, $V_{IC} = 0\text{ V}$, $R_S = 50\ \Omega$, See Note 6		1.1	10		1.1	10		1.1	10	mV
α_{VIO}	Average temperature coefficient of input offset voltage		1.8			1.1			1.7		$\mu\text{V}/^\circ\text{C}$
I_{IO}	Input offset current (see Note 4) $V_O = V_{DD}/2$, $V_{IC} = V_{DD}/2$		0.1			0.1			0.1		pA
I_{IB}	Input bias current (see Note 4) $V_O = V_{DD}/2$, $V_{IC} = V_{DD}/2$		0.6			0.6			0.6		pA
V_{ICR}	Common-mode input voltage range (see Note 5)	-0.2 to 4	-0.3 to 4.2		-0.2 to 4	-0.3 to 4.2		-0.2 to 4	-0.3 to 4.2		V
V_{OH}	High-level output voltage $V_{ID} = 100\text{ mV}$, See Note 6	3.2	3.8		3.2	4.1		3.2	3.9		V
V_{OL}	Low-level output voltage $V_{ID} = -100\text{ mV}$, $I_{OL} = 0$		0	50		0	50		0	50	mV
A_{VD}	Large-signal differential voltage amplification $V_O = 0.25\text{ V}$, See Note 6	5	23		50	700		25	170		V/mV
CMRR	Common-mode rejection ratio $V_{IC} = V_{ICRmin}$	65	80		65	94		65	91		dB
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$) $V_{DD} = 5\text{ V to }10\text{ V}$, $V_O = 1.4\text{ V}$	65	95		70	97		70	93		dB
I_{DD}	Supply current $V_O = V_{DD}/2$, $V_{IC} = V_{DD}/2$, No load		1.4	3.2		0.02	0.034		0.21	0.56	mA

operating characteristics, $V_{DD} = 5\text{ V}$, $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS		TLC252Y			TLC25L2Y			TLC25M2Y			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Slew rate at unity gain	$C_L = 20\text{ pF}$, See Note 6	$V_I(PP) = 1\text{ V}$		3.6			0.03		0.43		V/ μs	
		$V_I(PP) = 2.5\text{ V}$		2.9			0.03		0.40			
V_n	Equivalent input noise voltage $f = 1\text{ kHz}$, $R_S = 20\ \Omega$			2.5			68		32		$\text{nV}/\sqrt{\text{Hz}}$	
B_{OM}	Maximum output-swing bandwidth $V_O = V_{OH}$, $C_L = 20\text{ pF}$, $R_L = 10\text{ k}\Omega$			320			5		55		kHz	
B_1	Unity-gain bandwidth $V_I = 10\text{ mV}$, $C_L = 20\text{ pF}$			1.7			0.085		0.525		MHz	
ϕ_m	Phase margin $f = B_1$, $C_L = 20\text{ pF}$, $V_I = 10\text{ mV}$			46°			34°		40°			

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.
5. This range also applies to each input individually.
6. For low-bias mode, $R_L = 1\text{ M}\Omega$; for medium-bias mode, $R_L = 100\text{ k}\Omega$, and for high-bias mode, $R_L = 10\text{ k}\Omega$.



PARAMETER MEASUREMENT INFORMATION

single-supply versus split-supply test circuits

Because the TLC252, TLC25L2, and TLC25M2 are optimized for single-supply operation, circuit configurations used for the various tests often present some inconvenience since the input signal, in many cases, must be offset from ground. This inconvenience can be avoided by testing the device with split supplies and the output load tied to the negative rail. A comparison of single-supply versus split-supply test circuits is shown below. The use of either circuit gives the same result.

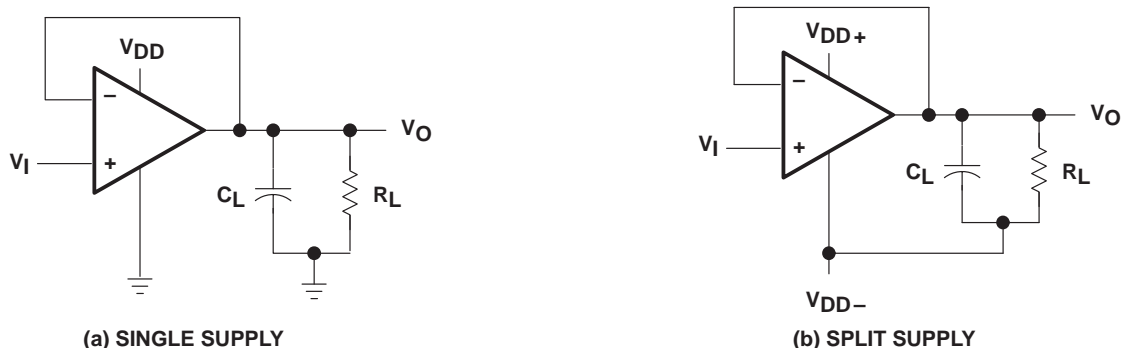


Figure 1. Unity-Gain Amplifier

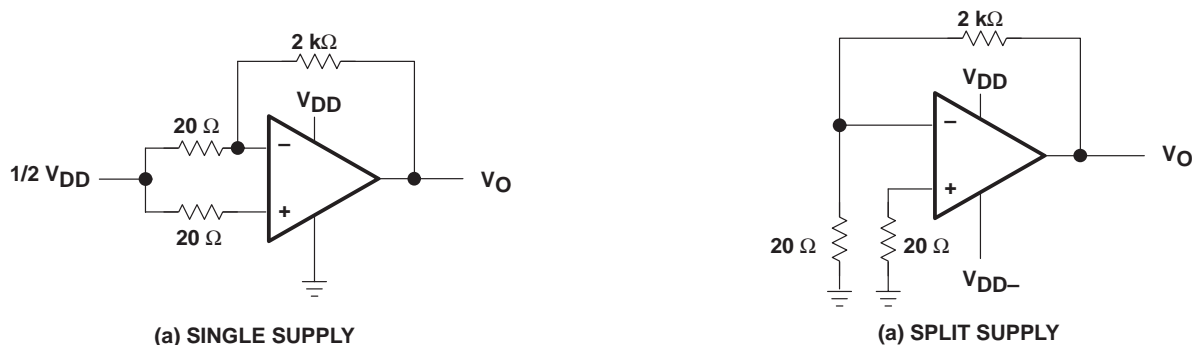


Figure 2. Noise-Test Circuit

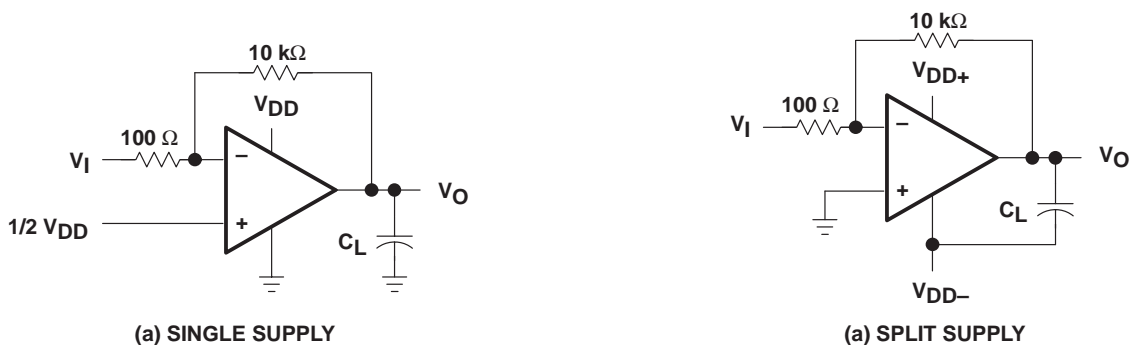
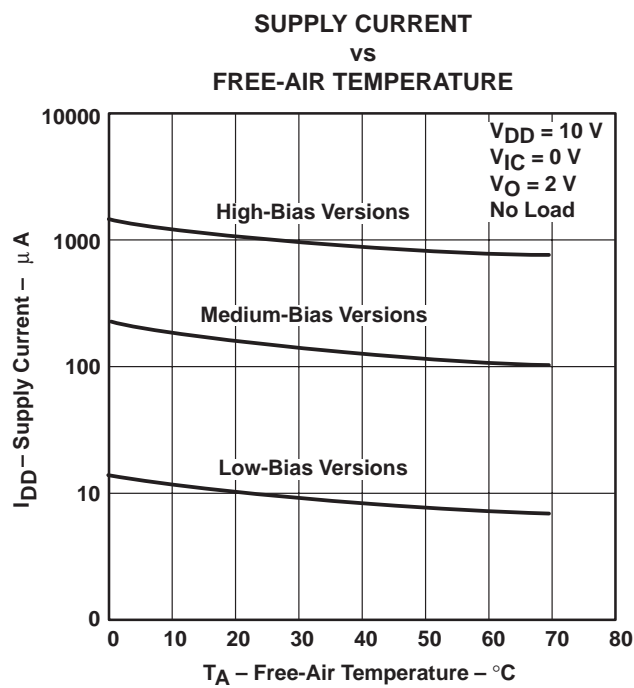
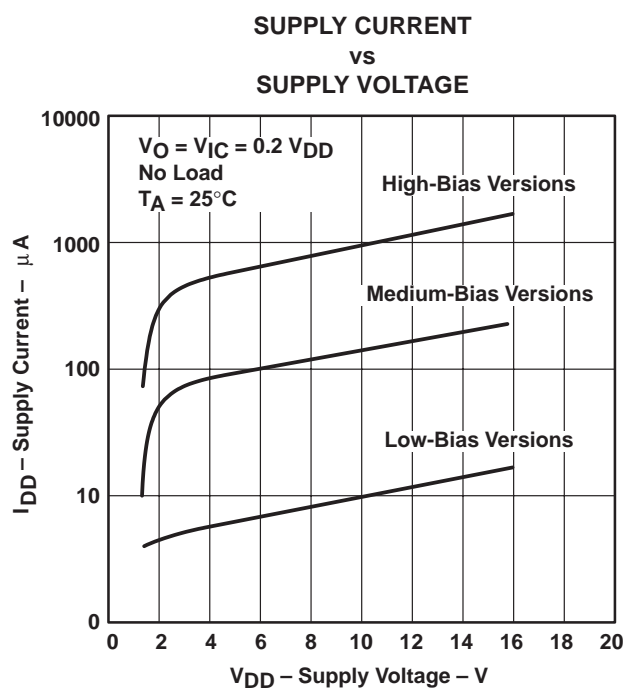


Figure 3. Gain-of-100 Inverting Amplifier

TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
I_{DD}	Supply current	vs Supply voltage	4
		vs Free-air temperature	5
A_{VD}	Large-signal differential voltage amplification	Low bias vs Frequency	6
		Medium bias vs Frequency	7
		High bias vs Frequency	8
	Phase shift	Low bias vs Frequency	6
		Medium bias vs Frequency	7
		High bias vs Frequency	8



TYPICAL CHARACTERISTICS

**LOW-BIAS LARGE-SIGNAL
 DIFFERENTIAL VOLTAGE AMPLIFICATION
 AND PHASE SHIFT
 vs
 FREQUENCY**

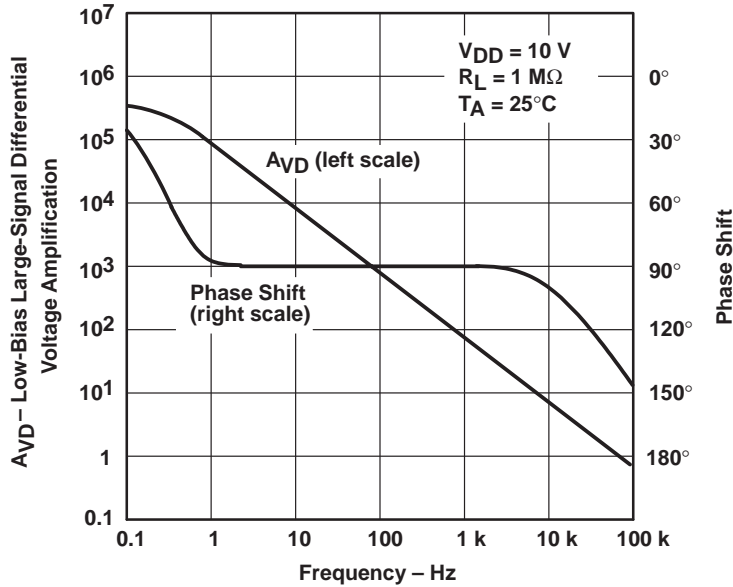


Figure 6

**MEDIUM-BIAS LARGE-SIGNAL
 DIFFERENTIAL VOLTAGE AMPLIFICATION
 AND PHASE SHIFT
 vs
 FREQUENCY**

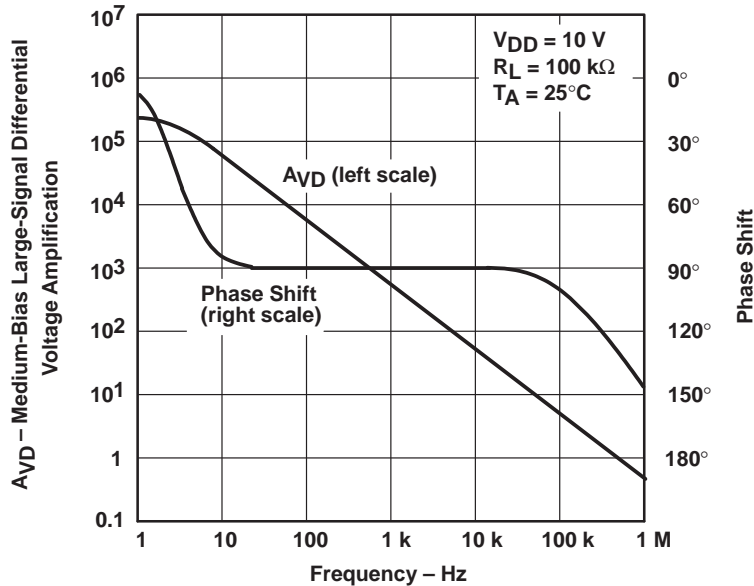


Figure 7

TYPICAL CHARACTERISTICS

HIGH-BIAS LARGE-SIGNAL
 DIFFERENTIAL VOLTAGE AMPLIFICATION
 AND PHASE SHIFT
 VS
 FREQUENCY

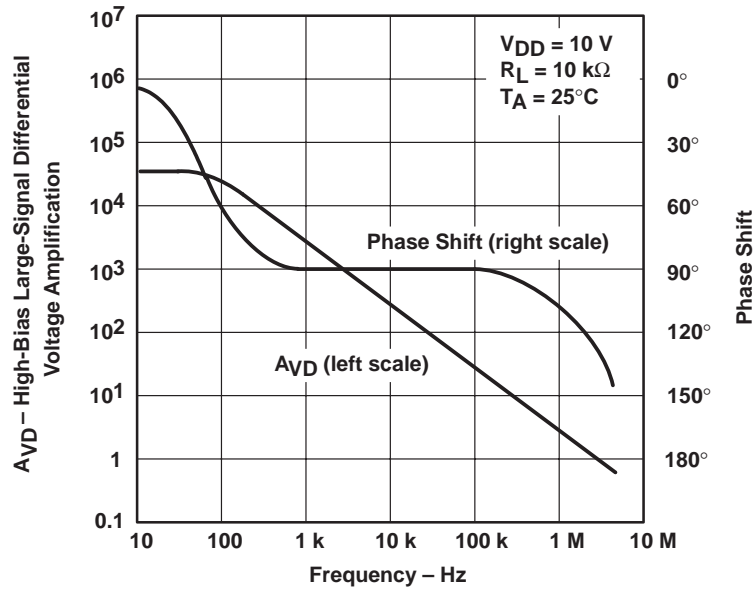


Figure 8

APPLICATION INFORMATION

latch-up avoidance

Junction-isolated CMOS circuits have an inherent parasitic PNP structure that can function as an SCR. Under certain conditions, this SCR may be triggered into a low-impedance state, resulting in excessive supply current. To avoid such conditions, no voltage greater than 0.3 V beyond the supply rails should be applied to any pin. In general, the operational amplifier supplies should be applied simultaneously with, or before, application of any input signals.

output stage considerations

The amplifier's output stage consists of a source-follower-connected pullup transistor and an open-drain pulldown transistor. The high-level output voltage (V_{OH}) is virtually independent of the I_{DD} selection and increases with higher values of V_{DD} and reduced output loading. The low-level output voltage (V_{OL}) decreases with reduced output current and higher input common-mode voltage. With no load, V_{OL} is essentially equal to the potential of V_{DD-}/GND .

supply configurations

Even though the TLC252/25_2C series is characterized for single-supply operation, it can be used effectively in a split-supply configuration if the input common-mode voltage (V_{ICR}), output swing (V_{OL} and V_{OH}), and supply voltage limits are not exceeded.

circuit layout precautions

The user is cautioned that whenever extremely high circuit impedances are used, care must be exercised in layout, construction, board cleanliness, and supply filtering to avoid hum and noise pickup, as well as excessive dc leakages.

IMPORTANT NOTICE

Texas Instruments and its subsidiaries (TI) reserve the right to make changes to their products or to discontinue any product or service without notice, and advise customers to obtain the latest version of relevant information to verify, before placing orders, that information being relied on is current and complete. All products are sold subject to the terms and conditions of sale supplied at the time of order acknowledgement, including those pertaining to warranty, patent infringement, and limitation of liability.

TI warrants performance of its semiconductor products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are utilized to the extent TI deems necessary to support this warranty. Specific testing of all parameters of each device is not necessarily performed, except those mandated by government requirements.

CERTAIN APPLICATIONS USING SEMICONDUCTOR PRODUCTS MAY INVOLVE POTENTIAL RISKS OF DEATH, PERSONAL INJURY, OR SEVERE PROPERTY OR ENVIRONMENTAL DAMAGE ("CRITICAL APPLICATIONS"). TI SEMICONDUCTOR PRODUCTS ARE NOT DESIGNED, AUTHORIZED, OR WARRANTED TO BE SUITABLE FOR USE IN LIFE-SUPPORT DEVICES OR SYSTEMS OR OTHER CRITICAL APPLICATIONS. INCLUSION OF TI PRODUCTS IN SUCH APPLICATIONS IS UNDERSTOOD TO BE FULLY AT THE CUSTOMER'S RISK.

In order to minimize risks associated with the customer's applications, adequate design and operating safeguards must be provided by the customer to minimize inherent or procedural hazards.

TI assumes no liability for applications assistance or customer product design. TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right of TI covering or relating to any combination, machine, or process in which such semiconductor products or services might be or are used. TI's publication of information regarding any third party's products or services does not constitute TI's approval, warranty or endorsement thereof.